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Information Transparency and Equilibrium Selection in Coordination Games: An Experimental Study

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Abstract

We experimentally investigate the role of information transparency for equilibrium selection in stag hunt coordination games. These games can be transformed from a prisoner's dilemma game by introducing a centralized reward or punishment scheme. We aim to explore the impact of the disclosure of information on how final payoffs are derived on players' incentive to coordinate on the payoff-dominant equilibrium. We find that such information disclosure significantly increases the tendency of players to play payoff-dominant action and reduces the occurrence of coordination failure. The mechanism works directly through the positive impact of disclosure on the saliency of the payoff-dominant equilibrium, and indirectly through the positive influence of disclosure on players' belief about the likelihood of cooperation by opponent.

Keywords: coordination games, equilibrium selection, information disclosure, centralized reward, centralized punishment

JEL Classification: A13, C72, C91, D81, D83

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1 Introduction

Humans are social beings; they interact constantly. They influence others and are influenced by others in their social surroundings. In order to survive, they need to cooperate with others and learn how to balance their individual interests with collective interests. To achieve a more socially desirable outcome they must learn how to coordinate their actions with other people to arrive at mutually consistent actions. Social conventions usually help people coordinate in social institutions (Skyrms 1996; Guala and Mittone 2010). However, coordination is often hampered by the failure to develop an implicit understanding of others' intention and the inability to trust others' inclinations to take a mutually desirable action. In such situations, people often prefer to take a safer alternative action that yields a smaller payoff. If everybody behaves in the same way, society is stuck with a less socially desirable outcome.

To illustrate this further, consider the example of an airline company whose workers must prepare an airplane for departure. A timely departure requires the successful coordination of effort by multiple parties such as flight attendants, gate agents, mechanics, caterers, etc. If any party underperforms, the other departments' endeavors to achieve on-time departure are wasted. Overall performance is thus dragged down by the underperforming party and the flight is delayed. If one party is unsure about the commitment of other parties, and is sufficiently risk averse, that party would respond by underperforming too. The desirable outcome can only be achieved if all parties are able to coordinate their efforts and are willing to trust others' willingness to choose a mutually consistent action. They should be able to communicate seamlessly with others; however, communication is often hampered by location separation and hierarchical organization structure. How to make agents coordinate tacitly for an efficient outcome is thus an important question.

In game theory, a coordination setting like the one described above is usually depicted as coordination games. These are a class of games with pure strategy Nash equilibria that can be Pareto ranked. Equilibrium analysis of such games lacks the predictive power to foresee which equilibrium the players might end up with. Harsanyi and Selten (1988) propose the refinement concepts of payoff-dominance and risk-dominance. An equilibrium is said to be payoff-dominant if it is Pareto-superior relative to other equilibria. An equilibrium whose deviation losses are greatest is said to be risk-dominant. In other words, strategies constituting the risk-dominant equilibrium are relatively safe under strategic uncertainty. Harsanyi and Selten (1988) argue that payoff dominance should serve as the equilibrium-selection criterion in coordination games. Harsanyi (1995) subsequently proposes a new theory of equilibrium selection and suggests that probability mixtures of multiple Nash Equilibria could be the solutions.

Coordination games with multiple Pareto-ranked equilibria have received the lion's share of attention in the experimental economics literature (see Devetag and Ortmann 2007). However, ample experimental evidence has shown that people often fail to coordinate on the payoff-dominant equilibrium (Cooper et al. 1990), especially when the group size is large (Van Huyck et al. 1990). The secure and inefficient risk-dominant equilibrium is more likely to be chosen, leading to coordination failure.[1]

Numerous experimental studies have explored the determinants of coordination outcome. Various factors that affect the ability of subjects to overcome coordination failure have been examined. These factors can roughly be classified into two categories. The first category comprises those factors that are related to the payoff structure (i.e., the magnitudes of payoffs obtained from coordination); the second comprises contextual factors, such as the subject matching protocol, subject experience, availability of information, and the presence of external advice.

Some studies have examined the role of differences in payoff structure. Battalio et al. (2001) show that there is a positive correlation between the occurrence of risk-dominant equilibrium and the optimization premium, the latter defined as the pecuniary incentive accrued from the difference between the payoff from the best response and the payoff from the inferior response to a partner's strategy. Battalio et al. vary the size of the optimization premium across experimental treatments. Brandts and Cooper (2006a) show that increasing the bonus rate for successful coordination effectively reduces coordination failure even in the presence of a history of coordination failure. The effect sustains regardless of the magnitude and the duration of the bonus. This suggests that the presence of financial incentives that enhance the payoffs from coordination, even if they are only offered temporarily, can achieve a more efficient outcome than that achieved without financial incentives. Crawford et al. (2008) show that in coordination games, where the games are made realistic by describing

[1]To be consistent with the literature, we refer to cases where people coordinate on the inefficient equilibrium instead of the Pareto-superior equilibrium as coordination failures.

them using salience labels (focal points),[2] even a small asymmetry in payoffs accrued to players is enough to soften the effectiveness of a salience label in enhancing coordination. Relative to a treatment where payoffs are symmetric, the presence of a small payoff asymmetry would increase the incidence of coordination failures by around 30 percent.

The above studies belonging to the first category have one thing in common, namely varying magnitudes of payoffs across experimental treatments. Their focus is the effect of differences in the magnitudes of payoffs in mitigating coordination failure.

In contrast, in the second category the magnitudes of payoffs across treatments are identical. Treatments are only distinguished by the underlying environment of the coordination games. Changing the contextual factors is often a more economical way to facilitate coordination than changing the magnitudes of payoffs. Its objective is to reduce uncertainty about opponents' behavior and to facilitate better communication between players in order to develop an implicit mutual understanding and to provide assurance to players that others would likely play the payoff-dominant action.

Among studies belonging to the second category, Cooper et al. (1992) study the role of one-way and two-way communication between players in mitigating coordination failure. They show that two-way communication is more effective. Van Huyck et al. (1992), Bangun et al. (2006), and Chaudhuri et al. (2009) study the role of non-binding external advice given to players to encourage them to adopt a payoff-dominant action. They show that the presence of external advice strengthens players' belief in other players' willingness to adopt payoff-dominant action and thereby facilitates coordination. Berninghaus and Ehrhart (2001) and Brandts and Cooper (2006b) investigate the effect of information on opponents' strategy in overcoming coordination failure. They find that revealing opponents' previous decisions (either the distribution of group members' decisions or each individual group member's decision) is effective in overcoming coordination failure.

However, these decentralized methods usually require stringent execution since a slight deviation from mutually optimistic beliefs may lead to coordination failure. For instance, two-way communication (where both players send out messages) is effective while one-way (only one player sends out messages) is not (Cooper et al. 1992); arbiters' assignments are

[2] In their experiment, the coordination games are depicted as a hypothetical setting where a pair of subjects agree to meet up but cannot confirm beforehand their meeting takes place. Two alternative places are given: one is made salient by representing it as a landmark building (e.g., the Chicago Sears Tower) while the other is a small, unknown building (e.g., the AT&T building).

credible only when they do not violate payoff dominance and symmetry (Van Huyck et al. 1992); advice from predecessors has to be "common knowledge" as a slight deviation from it (i.e., advice that is "almost common knowledge") may not work (Chaudhuri et al. 2009).

Our study follows the line of research exploring the use of contextual factors to overcome coordination failure. Using 2x2 stag hunt coordination games, we study the effectiveness of the disclosure of information on the governance mechanism determining the payoff from every pair of possible strategies that subjects may choose. More specifically, the governance mechanisms we examine in this paper are the centralized reward and punishment schemes. Note that the focus of this paper is not on the use of reward or punishment themselves in facilitating coordination per se, but rather on the information of the underlying mechanism determining payoffs. The games played in the control and experimental treatments are identical. The payoff structures in these treatments are exactly the same. However, in the control treatment, we only present the final payoffs from coordination, while in the other treatment we provide detailed information on how those final payoffs are derived using the centralized reward and punishment schemes. Essentially, when these details are provided, subjects can see that there is a reward scheme behind the payoffs accrued from the payoff-dominant equilibrium and a punishment scheme behind the payoffs accrued from the risk-dominant equilibrium. We also elicit subjects' beliefs about their opponent's behavior, which may shed some light on the channels through which the mechanism works.

Thus, in this paper, information transparency refers to the availability of detailed information about the institutional setting underlying the decision context and the process with which the final payoffs are determined. We choose a centralized punishment and reward scheme as an example of such context and process. Note that, obviously the centralized reward and punishment is not the only instrument that can transform a prisoner's dilemma game to a coordination game. Indeed, even in the absence of it or any other instrument, it is possible that a prisoner's dilemma game can be perceived and treated as a coordination game when individuals are sufficiently other-regarding (Rabin 1993; Fehr and Schmidt 1999; Tabellini 2008; Ellingsen et al 2012; Cason et al 2015). For instance, when individuals are inequality averse and are envious when facing disadvantageous inequality and compassionate when facing advantageous inequality in the spirit of Fehr and Schmidt (1999), there would be a threshold level of envy and compassion that would induce them to perceive a prisoner's dilemma game as a coordination game.[3] The inequality aversion subjectively alters the magnitude of payoffs accrued from all possible pair of strategies. However, across individuals the levels of envy and compassion are heterogeneous. Thus, whether or not a prisoner's dilemma game is perceived as a coordination game depends on subjects' degree of inequality aversion, which is unobservable to the experimenter.

In contrast, in this paper, our participants play the exact same coordination game albeit facing different information setting. In the baseline treatment they do not receive information on how the payoffs from the coordination game are derived while in the other treatment they do. Thus, in our study subjects uniformly faces a coordination game and see the game as a coordination game rather than a prisoner's dilemma game.[4] As we stressed it earlier, our study does not focus on the comparison between punishment and reward per se, but rather on the evaluation of how information provision enhances coordination. Essentially, information transparency increases the saliency of the payoff dominant equilibrium and positively influences individuals' belief about the likelihood of cooperative play by opponent.

Our study contributes to the literature in the following ways. Firstly, to the best of our knowledge, this is the first study to use information on how the payoffs from coordination are derived to facilitate coordination. Secondly, we show that the effect of information on players' incentive to coordinate on the payoff-dominant equilibrium differs depending on the nature of the information provided.

The main findings are as follows. We find that revealing information about institutional rules regardless of the mechanism effectively increases payoff-dominant action, thus substantially reducing coordination failure. Information about the reward mechanism helps sustain the play of the payoff-dominant strategy over time, and information about the punishment mechanism even slightly increases cooperation during the course of the

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[3] We thank an anonymous referee for pointing this out. For example, assuming that the utility of an inequality averse individual is $U_i = x_i - \alpha_i max[(x_j - x_i); 0] - \beta_i \max[(x_i - x_j); 0]$ for $i \neq j, \alpha \geq 0,$ and $\alpha > \beta.$ The individual's degree of envy is captured by α and the degree of compassion is captured by β. It is straightforward to verify that the original prisoner's dilemma game we used in this paper (see Figure 1) will be perceived as a coordination game if $\alpha \geq 0$ and $\beta > \frac{1}{4}$.

[4] It can be straightforwardly shown that an inequality averse individual with Fehr and Schmidt utility function would still perceive stag hunt games 1 and 2 presented in Figure 1 as stag hunt games regardless of how averse he (she) is to advantageous or disadvantageous inequality. Indeed, both (C, C) and (D, D) would remain as equilibria for all admissible values of α and β.

experiment. Both types of information increase agents' beliefs[5] that the opponent will cooperate while the latter also shows direct positive effects on actions. In addition, we posit that the presence of punishment or reward may make the payoff-dominant equilibrium more salient rather than changing people's preferences.

We proceed as follows. Section 2 introduces the experimental design. Section 3 discusses the main experimental results. Section 4 presents a further analysis where the presence of centralized punishment and reward would not transform the original prisoner's dilemma game into a coordination game. Finally, Section 5 concludes the paper.

2 Experimental Design

There were two types of stag hunt games in our experiment. Each was played in both experimental and control conditions. The experimental and control treatments differed only in the information revealed. In other words, games played in these two treatment conditions were essentially identical. We will give details of the treatment conditions in the next subsection. Before subjects made their decisions, we asked them to predict the likelihood of their opponent making a cooperative decision. Beliefs have been found to be closely related to decisions in the literature (see, e.g., Charness and Dufwenberg 2006; Croson 2007). It has been suggested that contextual factors affect behavior through beliefs (Dufwenberg et al. 2011; Ellingsen et al. 2012). Belief elicitation allows us to explore how information about institutional rules shapes beliefs, which in turn spells action. Note that the revealed information about institutional rules may have a hybrid quality (i.e., shaping behavior through beliefs and shaping action directly). It would be interesting to see whether information about institutional rules regarding punishment and reward functions through different channels.

In addition to beliefs, we also elicited subjects' risk attitude. It has been shown in the literature that risk preferences and decisions under strategic uncertainty are closely related. For instance, risk preferences relate to trust (Bohnet and Zeckhauser 2004; Schechter 2007), coordination (Heinemann et al. 2009), behavioral patterns deviating from Nash in matching pennies games (Goeree et al. 2003), and contribution in public goods games (Teyssier 2012). We used the multiple price list method similar to the one used by Holt and Laury (2002).

[5] Unless stated otherwise, "beliefs" throughout this paper means agents' beliefs that the other player will cooperate. It measures the subjective probability that the other player would cooperate.

Subjects were presented with 10 paired choices, one of which (option A) generated a deterministic payoff and the other (option B) generated two possible payoffs with certain probabilities. Table 1 presents the paired choices used in this risk elicitation. A risk neutral person would switch from option A to option B at line 5. The later the switch, the more risk averse the individual. The switching point informs us about one's risk attitude.

[Enter Table 1 Here]

2.1 Experimental Treatments

There were four treatments altogether. Figure 1 presents all the games involved in our experiment.[6] Subjects in all treatments played either stag hunt game 1 or stag hunt game 2. In the two experimental treatments, subjects were given information on how the stag hunt game is developed from the prisoner's dilemma game by introducing punishment or reward. The other two treatments served as baselines where subjects played stag hunt games without any information on the transformation process. Comparison between the experimental and baseline treatments sheds light on how revealed information affects equilibrium selection. In what follows, we explain the treatment conditions in detail.

[Enter Figure 1 here]

The punish_stag1 treatment

In this treatment, subjects played the stag hunt game 1 shown in Figure 1, however in addition were also informed that the stag hunt game 1 is transformed from the prisoner's dilemma game (pd game) shown in Figure 1 using a S$2 punishment scheme imposed on the unilateral defector. Consequently, if a subject unilaterally defects from C to D, her payoff is only S$2 instead of S$4. The revealed information on punishment serves as a reminder that defection is a discouraged behavior. Compared to the original pd game, defection becomes a less attractive strategy, too.

[6]In the instructions, we refer to players as "ROW" or "COLUMN" player. Their strategies "C" and "D" are referred to "Up" and "Down" for the row player, and "Left" and "Right" for the column player. We use "C" and "D" hereafter for convenience.

The reward_stag2 treatment

Subjects played the stag hunt game 2 indicated in Figure 1. Again, the transformation process was revealed to the subjects. The original basic game is the same prisoner's dilemma game as that in the punish_stag1 treatment. A S$2 reward for mutual cooperation is introduced, which transforms the game into stag hunt game 2. That is, if both subjects manage to mutually cooperate, each of them receives S$5 instead of only S$2. The revelation of the reward mechanism serves as a reminder that cooperation is a more attractive strategy and is encouraged by the central planner.

The baseline treatments (stag1 & stag2)

We have two baseline treatments. The first one is stag1 treatment, which serves as the baseline treatment for the punish_stag1 treatment, and the second one is stag2 treatment, which serves as the baseline treatment for the reward_stag2 treatment. In these two baseline treatments, subjects simply played stag hunt game 1 and 2 without any information about mechanisms that transform the original prisoner's dilemma game into the stag hunt games.

2.2 The Procedures

The experiment was conducted at Nanyang Technological University and was programmed using z-Tree (Fischbacher 2007). We conducted two sessions each for the punishment_stag1 and the reward_stag2 treatments and four sessions each for the stag1 and the stag2 treatments. The number of subjects in each session ranged from 20 to 26. In total, 292 subjects participated in the experiment. Each session lasted around 70 minutes on average. The average earnings were about S$20 (roughly US$16), including a S$2 show-up fee. All subjects were recruited through a university-level email system. They came from various academic backgrounds, including science, engineering, social science, and business. We had a between-subject design so that each subject only participated in one session. No one had participated in a similar experiment before.

The experiment consisted of two stages. The first was the main game stage, followed by risk preference elicitation in the second. We provided hard-copy instructions on paper as well as on screen. The paper instructions were read aloud by an experimenter before the experiment started.[7] All questions were answered in private. Subjects played two practice periods and then proceeded to play 25 real periods. Each player's role (row or column player)

[7]The instructions used in the experiment can be found in the appendix.

was randomly drawn every period. The pair composition was reshuffled from period to period, too.

Before subjects made their decision in every period, they were asked to make a prediction about their opponent's propensity to cooperate. The prediction was incentivized to elicit true beliefs. One out of 25 predictions was randomly selected as the payment foundation for belief elicitation. If the prediction fell into the correct range, an extra S$4 would be added to payment. No feedback on beliefs was given until subjects finished the 25 periods of play. However, subjects were informed of their opponent's decision at the end of each period. Among the 25 real periods, five were randomly selected as the payment for the decision part. After playing the game for 25 periods, subjects entered into the risk preference elicitation stage. Their choice in one out of ten lines was randomly selected as the payment for the second stage. This completed the experiment. Subjects were asked to complete a questionnaire regarding demographics after the experiment.

3 Experimental Results

In this section, we start with a descriptive summary of the experimental results, followed by some regression analyses. As a robustness check and also an extension of the current study, we also briefly present results from three additional treatments whereby subjects play the prisoner's dilemma game rather than stag hunt coordination game. That is, in these three additional treatments the amount of reward and punishment is smaller than the amount set in the our main treatments, such that the original prisoner's dilemma game would remain as the prisoner's dilemma game rather than being transformed into a coordination game.

3.1 Data Summary

Figure 2 illustrates the mean cooperation rate over time in all treatments. Note that games played in the punish_stag1 and stag1 treatments, and the reward_stag2 and stag2 treatments were identical, respectively. The only difference between the two treatments is that subjects in the former treatment were informed of the original prisoner's dilemma game and the transformation process involving punishment or reward.[8] It can be seen that the starting

[8] In the punish_stag1 and the reward_stag2 treatments, subjects were presented with both the stag hunt game and the original prisoner's dilemma game, one might question if subjects understood the game. To prove that subjects did understand the game, we compared the cooperation rate in the prisoner's dilemma treatment (a treatment where subjects played the original prisoner's dilemma game) to that in the stag1 and stag2 treatments

cooperation rates in all treatments are almost identical and they remain relatively close to each other in the first five periods. Cooperation rates start to diverge after period 5.

[Enter Figure 2 Here]

Cooperation rates in the punish_stag1 and reward_stag2 treatments, where institutional rules were revealed, were generally higher than in the baseline treatments. The differences between punish_stag1 and stag1, and reward_stag2 and stag2 are both statistically significant (two-sided Mann-Whitney test, punish_stag1 vs stag1, p-value < 0.01; reward_stag2 vs stag2, p-value $= 0.03$).[9] The difference between punish_stag1 and stag1 is larger, which suggests that revealing information about the punishment system might work better in terms of promoting cooperation.[10]

Punishment reduces the payoff from defection while keeping the payoff from mutual cooperation unchanged. Consequently, unilateral defection becomes relatively less attractive than cooperation, and in turn it makes the payoff dominant equilibrium more salient. In contrast, reward increases the payoff from mutual cooperation while keeping the payoff from defection unchanged. It will thus also make unilateral defection relatively less attractive than cooperation, which will make the payoff dominant equilibrium more salient. In sum, both punishment and reward make the payoff dominant equilibrium more salient albeit through different channels. As a result, we should expect that the treatment with either punishment or reward should yield higher coordination rate on the payoff dominant outcome (C, C) than the standard prisoner's dilemma treatment. Our result indeed shows that this is the case.

In the baseline stag-hunt treatment (stag 1 or stag 2), subjects are shown the final payoffs from all pairs of strategies but not the initial prisoner's dilemma game and the punishment or

(the control stag hunt games). It shows that the cooperation rate (C,C) in the prisoner's dilemma game (see the bar chart for (C,C) in Pd treatment shown in Figure 5) is much lower than that in the stag hunt games (see the bar charts for (C,C) in Stag1 and Stag 2 shown in Figure 3). This suggests that subject did respond differently to the differing contingencies in these different types of games.

[9] We used subject averages across periods as units of observation, following Charness et al (2007).Specifically, for each subject we calculated the average cooperation rate over the 25 periods and used it as a unit of observation. That is to say, the number of observations is the number of subjects in each treatment (punish_stag1: N= 52; stag1: N = 96; reward_stag2: N = 52; stag2: N = 92). It is to eliminate correlation over time. This type of tests throughout the paper follows similar suit unless otherwise stated.

[10] It is well documented that punishment works better than reward in terms of promoting cooperation (Sigmund et al. 2001; Sefton et al. 2007). Interested readers may refer to an excellent review on this topic by Balliet and Mulder (2011).

reward mechanism. Notice that the payoffs used as the basis for making decisions in stag 1, stag 2, punish_stag1 and reward_stag2 treatments are exactly identical. The major difference is, however, in punish_stag1 and reward_stag2 treatments the information on the centralized punishment and reward scheme would make the payoffs from the payoff dominant equilibrium more salient. We show that the increase in saliency leads to higher rate of mutual cooperation.

The next question is on the comparative performance of punishment and reward. Which of the mechanism would be more effective in encouraging mutual cooperation? Prospect theory (Kahneman and Tversky, 1979) tells us that people are loss averse. When faced with information on punishment, people may put themselves into the prisoner's dilemma game setting and they feel a loss with the implementation of punishment compared to what they would get without the punishment. The aversion to the sense of loss might induce people to cooperate more. Our results show that indeed punishment is more effective than reward in motivating people to coordinate on the payoff dominant equilibrium.

There seem to be different evolutionary patterns over time across treatments. It appears that the cooperation rate up to period 15 decays over time in the two baseline treatments. From period 15 onwards, the cooperation rate is relatively stable at around 55% in the stag2 treatment and 40% in the stag1 treatment. In contrast, it increases slightly over time and reaches almost full cooperation at the end in the punish_stag1 treatment. The cooperation rate remains relatively stable at around 75% over time in the reward_stag2 treatment. The observation trends are verified by non-parametric tests. Using the average cooperation rate in the first five periods and the last five periods as units of observation, we find that the cooperation rate in the late periods is significantly higher in the punish_stag1 treatment (two-sided Wilcoxon matched-pairs signed-ranks test, $\text{p-value} < 0.01$), significantly lower in the two baseline treatments ($\text{p-value} < 0.01$ in both the stag1 and stag2 treatments), and not significantly different from that in early periods in the reward_stag2 treatment ($\text{p-value} = 0.72$).

Beliefs are found to be closely related to cooperation (Spearman rank correlation tests, $\text{p-value} < 0.01$ in all treatments). The distribution of average beliefs is similar to the distribution of cooperation rates presented in Figure 2. Likewise, we find significant differences of belief between punish_stag1 and stag1, and reward_stag2 and stag2. The evolutionary patterns of beliefs are consistent with the trend of cooperation rates, too.

Figure 2 indicates that people have a higher tendency to cooperate if institutional rules are made transparent to them. Figure 3 delineates the extent to which such information sharing helps solve the coordination problem. It shows the distribution of mutual cooperation (the payoff-dominant equilibrium), mutual defection (the risk-dominant equilibrium), and disequilibrium outcomes by treatment.

[Enter Figure 3 Here]

Compared with the control stag1 treatment, there is a substantial decrease in mutual defection and a massive increase in mutual cooperation in the punish_stag1 treatment. In addition, disequilibrium outcomes decrease. Revealing the punishment mechanism that yields the final payoffs in the punish_stag1 game effectively solves the coordination problem. People settle with the payoff-dominant equilibrium much more frequently than the risk-dominant equilibrium and end up with fewer disequilibrium outcomes. Information about the reward mechanism also helps people to coordinate on the payoff-dominant equilibrium albeit to some lesser degree. There is more mutual cooperation and less mutual defection in the reward_stag2 treatment than in the stag2 treatment. However, the improvement in coordination is of a smaller magnitude than that in the punish_stag1 treatment. In contrast to the decreased disequilibrium outcomes in the punish_stag1 treatment, disequilibrium outcomes slightly increase in the reward_stag2 treatment. This suggests that sharing information on mechanisms involving punishment and reward has different effects and may possibly work in different ways. We explore this issue in more detail in later sections. [11]

3.2 Regression Analyses

Here we explore the formation of beliefs and the decision to cooperate.

Table 2 presents OLS estimates of the determinants of subjects' beliefs about their opponent's decision. This belief is expressed as the likelihood that the opponent will

[11] Our study relates to framing in a broad sense as the result is affected by how the game is described. In this strand of literature (e.g., see Erev and Roth 2014 for a review), it has been found that framing seems to come into effect through initial beliefs and therefore the explanatory power of it might be stronger in early periods (Cooper et al. 1990). As a result, the smaller difference between treatments in early periods might be more informative. To verify this, we present the distribution of decision pair types for the first 10 periods in figure A3 in supplementary appendix A. Observational conclusions from comparisons between treatments remain the same. We thank an anonymous referee for comments in this regard.

cooperate. Regressors include Period ($Period$), the subject's belief in the previous period (*Belief (t-1)*), the opponent's decision in the last three periods (*Others' Decision (t-1), Others' Decision (t-2), Others' Decision (t-3)*),[12] and the treatment dummy for the punish_stag1 treatment (*Punish_stag1*), the treatment dummy for the reward_stag2 treatment (*Reward_stag2*).

The belief formation process follows that used in Fischbacher and Gächter (2010), who find that in the context of public goods games, a subject's belief in period t is a weighted average of her belief in period $t-1$ and other group members' behavior in period $t-1$. In contrast with their findings that other group members' behavior in earlier periods has no significant effects on the belief formation in the current period, these variables do show significant effects in our study and thus three lags are included in the model.

[Enter Table 2 Here]

The left-hand panel estimates the belief formation in the stag hunt game 1, including the punish_stag1 and stag1 treatments. The right-hand panel estimates the belief formation process in the other stag hunt game. Belief in the previous period always has significantly positive effects on belief in the current period. The coefficient is of a substantial magnitude in both panels and is the main factor affecting belief in the current period. The opponent's decisions in the last three periods are all significantly positive in the left-hand panel. The third lag becomes insignificant in the right-hand panel. In both panels, the significance of the opponent's decision decreases substantially after the first lag. The treatment dummies for punish_stag1 and reward_stag2 are both positively significant. That is to say that after controlling for other variables, revealing information on the punishment or reward mechanism increases subjects' belief in their opponent's propensity to cooperate.[13][14]

[12]As we used a random matching protocol, the opponent is likely to be different in each of these three periods. The regressor refers to the decision of the opponent in that a particular period.

[13]Since a lagged dependent variable is used as a regressor, we also tried the "difference" and "system" generalized method-of-moments (GMM) dynamic panel estimation method for belief formation in individual treatments (Roodman 2009). However, the long panel T and relatively small N lead to an explosive number of instruments, which may generate bias in estimates as indicated by a perfect Hansen statistic of 1.000.

[14] We also present the results using only the first 10 periods in table A1 in the supplementary appendix A. Conclusions remain qualitatively the same except that the treatment dummy for the reward_stag2 treatment becomes insignificant. It might be because of a smaller difference between the reward_stag2 and stag2

So far we have shown that merely revealing institutional rules increases subjects' beliefs in their opponent's cooperative behavior. In what follows, we explore the determinants of decisions. Table 3 shows Probit estimates of the determinants of the cooperative decision. The dependent variable is a binary variable taking the value of 1 if the subject decides to cooperate and 0 otherwise. Explanatory variables are the subject's belief about their opponent's propensity to cooperate (*Belief*),[15] Period (*Period*), the number of safe options taken in the lottery (*No. of safe options*), and treatment dummies for the punish_stag1 and reward_stag2 treatments (*punish_stag1, reward_stag2*). The table also reports the marginal probability change at the sample mean of regressors while for binary variables, the marginal effects report the probability change when the indicator variable changes from 0 to 1.[16]

One's belief apparently carries a lot of weight in decision making. The coefficient is always positively significant and of a substantial magnitude. One is much more likely to cooperate if she believes her opponent will do so too. It has been shown earlier that revealing institutional rules helps increase subjects' belief in others' propensity to cooperate. This increased belief then leads to more cooperation. The effect of beliefs on behavior seems to be universal for both mechanisms. The risk attitude has mixed effects depending on the payoff structure of the coordination game. It has no effect in stag hunt game 1, where the difference in the cooperator's monetary payoff between the payoff-dominant equilibrium and disequilibrium is relatively small ($3\ vs\ 0$). The effect is marginally significant if the difference increases ($5\ vs\ 0$). The negative sign in the right-hand panel suggests that the more risk-averse a person is, the less likely she is to cooperate in stag hunt game 2. It might be the case that the more risk-averse person is, the less willing she is to take risks under strategic uncertainty if the cost of being a "sucker" is relatively high (i.e., the "sucker" gets 0 unless coordination is successful, in which case, she receives S$5). The treatment dummy for punish_stag1 is positively significant. This suggests that, controlling for other factors, revealing the punishment mechanism increases the likelihood of cooperation by 17

treatments before steady equilibrium is achieved. This result is consistent with the analysis on decision, which suggests that information on these two mechanisms may work differently.

[15]One may worry about the endogeneity of beliefs. On the one hand, it is not uncommon for belief to be used as a regressor in the literature (see, e.g., Charness and Dufwenberg 2006; Croson 2007; Fischbacher and Gächter 2010; Dufwenberg et al. 2011); on the other, we applied the two-stage least squares estimation method, treating belief as an endogenous variable. Our conclusion remains the same.

[16]As for belief formation and cooperation, we also applied the random effects model. Since the estimation results are very similar to OLS, only OLS results are reported.

percentage. However, we do not find similar effects regarding the reward mechanism, as indicated by the insignificant coefficient in the right-hand panel.[17]

[Enter Table 3 Here]

In summary, we find that revealing institutional rules helps increase subjects' belief in their opponent's propensity to cooperate, which improves their own cooperation. This channel is universal for both types of information (i.e., information on both punishment and reward mechanisms). In addition to affecting beliefs, revealing the punishment mechanism directly improves cooperation too. It seems to have a hybrid quality (i.e., affecting behavior both through beliefs and directly). However, we do not find a similar hybrid quality for information about the reward mechanism.

4. Institutional Rules in Prisoner's Dilemma Games

Thus far, we have analyzed the effects of revealing institutional rules on cooperation in stag hunt coordination games. It is noteworthy that in the absence of reward or punishment, the original game is a prisoner's dilemma game. The presence of reward or punishment transforms the prisoner's dilemma game into a coordination game, wherein cooperation becomes an equilibrium strategy. Consequently, if we observe that cooperation rate increases, we are not sure whether it is solely because the revealed institutional rules make the mutual cooperation equilibrium more salient or because the revealed punishment or reward mechanism changes people's preferences for cooperation. People might perceive the institutional rules as a signal from the central authority to encourage cooperation, making them more willing to cooperate.

To shed light on the issue, we ran three additional treatments using prisoner's dilemma games. In the current study, we have focused on stag hunt coordination games that were developed from prisoner's dilemma games by introducing punishment or reward. Coordination games were our baselines. To isolate equilibrium saliency from changed

[17] We present the results using the first 10 period in table A2 in the supplementary appendix A. Conclusions remain qualitatively unchanged.

preferences, we employed a set of prisoner's dilemma games where equilibrium saliency is absent as cooperation is no longer an equilibrium strategy. We used the prisoner's dilemma game in Figure 1 as the baseline in the added treatments, and implemented a punishment or reward mechanism. We chose the punishment or reward amount that is sufficiently small so that the game remained as a prisoner's dilemma game instead of being transformed into a stag hunt coordination game. Since cooperation is not an equilibrium strategy, more cooperation, if any, may be attributable to changed preferences for cooperation due to the punishment or reward mechanism. Mechanisms in prisoner's dilemma games were supposed to be more powerful in shaping preferences than those used in stag hunt games. Compared with the baseline, not only was the signal delivered that cooperation was encouraged and that defection was discouraged, but the actual payoff also changed because of the use of punishment and reward. However, information about punishment and reward was revealed by signal delivery and the payoff remained the same as the baseline in the stag hunt games.

We had two sessions for each treatment. The number of subjects in each session was either 24 or 26. The experimental procedure was similar to other treatments. In the baseline treatment (*pd treatment*), subjects played the prisoner's dilemma game shown in Figure 1. In the treatment with punishment (*punish_pd treatment*), subjects were shown the pd game and were told that there was a S$0.50 punishment for unilateral defection. In the treatment with reward (*reward_pd*), subjects were informed of the pd game and a S$0.50 reward for mutual cooperation. The payoff structure after punishment or reward was also displayed. Note that the game remained a prisoner's dilemma after punishment or reward was implemented.

Figure 4 delineates the average cooperation rate over time in the three treatments. The typical decaying trend over time appears in all three treatments. We do not see much difference between the experimental and baseline treatments. Using subjects' average cooperate rates over time as units of observation, none of the differences is statistically significant (two-sided Mann-Whitney test, pd vs punish_pd, p-value $= 0.85$; pd vs reward_pd, p-value $= 0.11$). The use of punishment and reward does not seem to increase cooperation.[18]

[Enter Figure 4 Here]

[18] The number of observations in each of treatment is thus equal to the number of subjects participating in each treatment. That is, N = 50 for the pd treatment, N = 50 for the punish_pd treatment, and N = 50 for the reward_pd treatment.

Figure 5 shows the distribution of types of decision pairs. The unique Nash equilibrium (i.e., mutual defection) is clearly the dominant type in all treatments. The proportion of the socially efficient outcome (i.e., mutual cooperation) is close to zero. We do not observe much difference between treatments. The use of punishment or reward in the prisoner's dilemma game does not make people cooperate more even though they are encouraged to do so. Therefore, behaviors do not seem to change in the presence of punishment or reward as long as the punishment and reward does not lead to a transformation of the original prisoner's dilemma game into a stag hunt coordination game. [19]

[Enter Figure 5 Here]

5 Conclusion

The goal of this paper was to study the role of information on institutional rules regarding the underlying reward and punishment mechanisms for equilibrium selection in stag hunt games. We had two experimental treatments with full information and two control treatments. In the full information treatment, subjects were informed how the prisoner's dilemma game was transformed into a stag hunt game by introducing reward or punishment. In the control treatment, this information was absent. We elicited subjects' beliefs about their opponent's behavior before each round of play. We were also interested to know how the revealed information shapes subjects' behavior by investigating the dynamics of their beliefs and decisions. To find out whether the presence of reward and punishment changes preferences, we added three additional treatments using the prisoner's dilemma game, where cooperation is not an equilibrium strategy.

Our results indicate that sharing information on institutional rules is effective in inducing cooperation. The occurrence of coordination failure is substantially reduced. Revealing information about the reward and punishment mechanisms increased subjects' belief in their opponent's propensity to cooperate, which in turn spells action. Besides working through beliefs, information about punishment mechanisms has direct positive effects on decisions.

[19] We present the result only using the first 10 periods in figure A3 in the supplementary appendix A. Comparisons between the results from the two treatments across all periods show that they are not much different.

We do not find similar direct effects on action for information about reward mechanisms. Moreover, the results from the prisoner's dilemma games suggest that the use of reward and punishment does not make people more willing to cooperate when cooperation is not an equilibrium strategy. Thus, we posit that the revelation of information about the reward and punishment mechanism makes the payoff-dominant equilibrium more salient rather than changing people's preferences.

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Tables and Figures

Table 1. The ten paired lotteries

Line	Option A	Option B	Expected payoff difference
1	$1	3 of 0%, 0 of 100%	$1
2	$1	3 of 10%, 0 of 90%	$0.70
3	$1	3 of 20%, 0 of 80%	$0.40
4	$1	3 of 30%, 0 of 70%	$0.10
5	$1	3 of 40%, 0 of 60%	-$0.20
6	$1	3 of 50%, 0 of 50%	-$0.50
7	$1	3 of 60%, 0 of 40%	-$0.80
8	$1	3 of 70%, 0 of 30%	-$1.10
9	$1	3 of 80%, 0 of 20%	-$1.40
10	$1	3 of 90%, 0 of 10%	-$1.70

Prisoner's dilemma game

	C	D
C	3, 3	0, 4
D	4, 0	1.5, 1.5

Stag hunt game 1

	C	D
C	3, 3	0, 2
D	2, 0	1.5, 1.5

Stag hunt game 2

	C	D
C	5, 5	0, 4
D	4, 0	1.5, 1.5

Figure 1. The games in our experiment

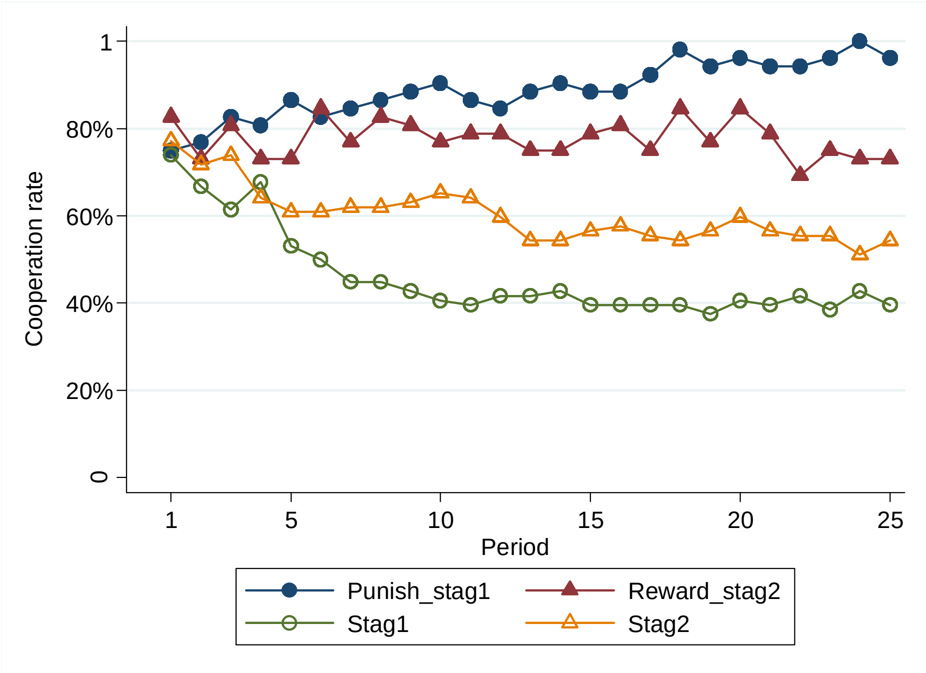

Figure 2. Mean cooperation rate over time in the coordination games

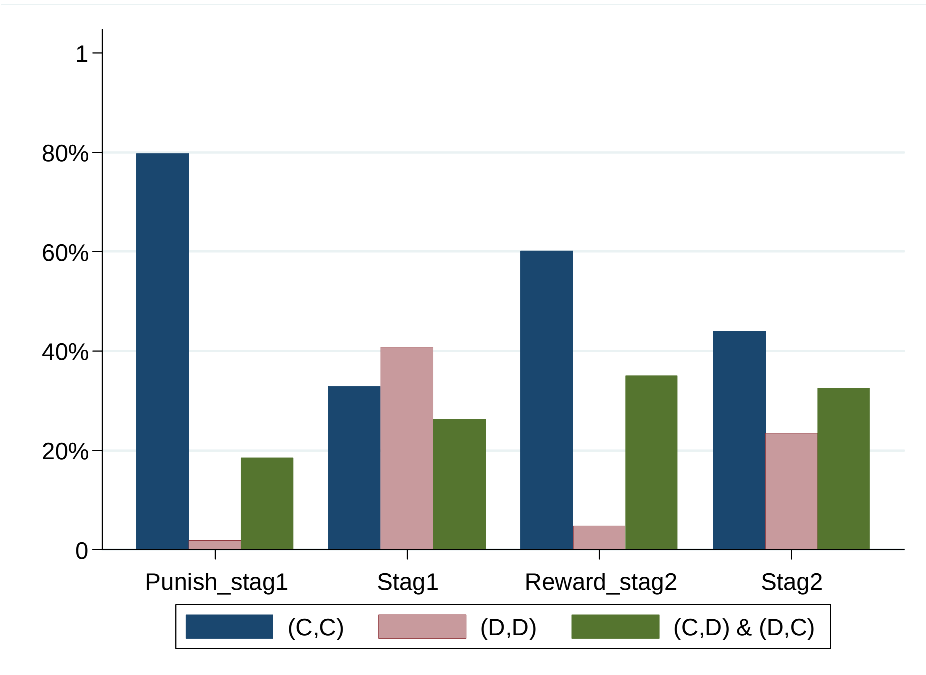

Figure 3. Distributions of decision pair type in the coordination games

Table 2. Belief formation in the coordination games

Dependent variable: Belief about the opponent's decision		
	Punish_stag1 vs Stag1	Reward_stag2 vs Stag2
Period	0.000	0.000
	(0.000)	(0.000)
Belief (t-1)	0.732***	0.813***
	(0.023)	(0.024)
Others' Decision (t-1)	0.101***	0.070***
	(0.008)	(0.007)
Others' Decision (t-2)	0.030***	0.013**
	(0.007)	(0.006)
Others' Decision (t-3)	0.031***	0.008
	(0.006)	(0.006)
Punish_stag1	0.018***	
	(0.006)	
Reward_stag2		0.012**
		(0.006)
Constant	0.047***	0.048***
	(0.009)	(0.011)
Observations	3,256	3,168
R^2	0.845	0.774

Note: OLS regressions with clustering on individuals. Robust standard errors in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 3. Cooperation in the coordination games

	Dependent variable: Cooperation decision = 1			
	Punish_stag1 vs Stag1		Reward_stag2 vs Stag2	
	Probit	Marginal effects	Probit	Marginal effects
Belief	5.291***	1.922***	4.100***	1.384***
	(0.276)	(0.113)	(0.423)	(0.153)
Period	-0.003	-0.001	-0.007	-0.002
	(0.005)	(0.002)	(0.004)	(0.001)
No. of Safe Options	-0.026	-0.010	-0.075*	-0.025*
	(0.039)	(0.014)	(0.042)	(0.014)
Punish_stag1	0.485***	0.169***		
	(0.180)	(0.059)		
Reward_stag2			0.163	0.054
			(0.189)	(0.062)
Constant	-2.716***		-1.597***	
	(0.234)		(0.391)	
Observations	3,700	3,700	3,600	3,600

Note: Probit regressions with clustering on individuals. Robust standard errors in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

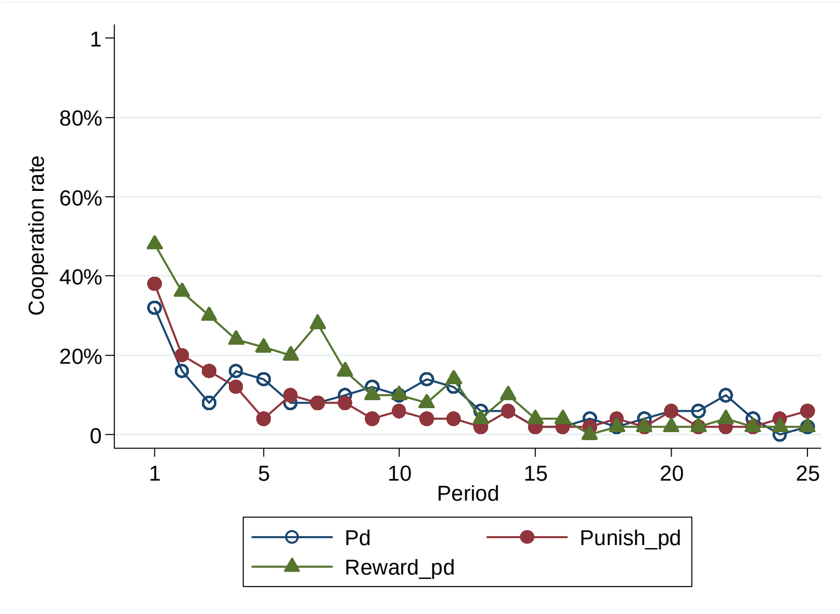

Figure 4. Mean cooperation rate over time in the prisoner's dilemma games

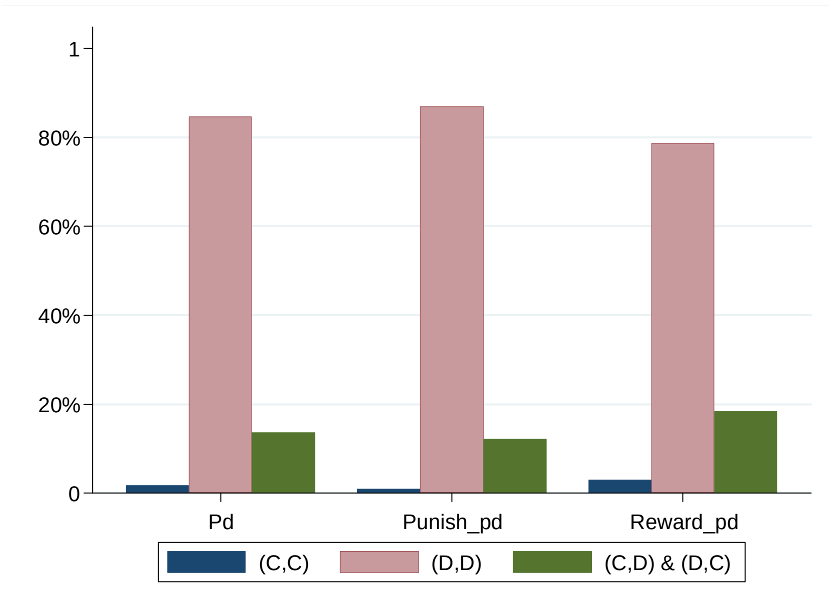

Figure 5. Type of decision pair in the prisoner's dilemma games